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Rock Island Arsenal Laboratory

TECHNICAL REPORT

PLASTIC FILMS: THEIR USEFULNESS IN THE FABRICATION OF TRANSPARENT BARRIER MATERIALS

By

L. W. Lynch

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Rock Island Arsenal
Rock Island, Illinois

ABSTRACT

Data is presented on the properties of ten recently received plastic films along with data on thirty-five films reported earlier.

Fifteen films, selected from this group as representative of plastic film types, were tested for fungus resistance, corrosiveness to metals, and stability to storage at elevated temperatures. Polyvinylidene chloride, rubber hydrochloride and polyvinyl chloride were found to be corrosive; cellophane and polyvinyl chloride are not fungus resistant; cellophane, polyvinylidene chloride and rubber hydrochloride have poor stability to storage; polyethylene, and polyvinyl chloride are rated as having only fair storage stability.

From the data on the individual films, it can be expected that composite films composed of either (1) fluorocarbon C (1/2 mil.) and a heat sealable polyester or (2) fluorocarbon C (1/2 mil.), a high strength second component and unoriented polypropylene would result in acceptable transparent barrier materials for military packaging applications.

RECOMMENDATIONS

It is recommended that a number of composite plastic films be fabricated, utilizing information contained in this report, and determinations made as to their value in military packaging applications.

It is recommended that studies be continued toward improving the heat-seal characteristics of polyesters.

It is recommended that polyvinylidene chloride and rubber hydrochloride film types not be used in contact with metals at temperatures above 90°F unless effective heat stabilizers have been incorporated into the product.

It is recommended that polyvinyl chloride film types not be used in contact with metals at temperatures above 130°F unless effective heat stabilizers have been incorporated into the product.

It is recommended that cellophanes not be used in tropical or subtropical climates unless an effective fungicide is present.

It is recommended that polyvinyl chloride film types not be used in tropical or subtropical climates unless the additives, such as plasticizers, used in its composition are fungus resistant.

PLASTIC FILMS: THEIR USEFULNESS IN THE FABRICATION OF TRANSPARENT BARRIER MATERIALS

CONTENTS

PLASTIC FILMS: THEIR USEFULNESS IN THE FABRICATION OF TRANSPARENT BARRIER MATERIALS

OBJECT

To provide the military packaging engineers with information concerning the usefulness of available flexible transparent plastic films in the preparation of composite films suitable for military packaging needs.

INTRODUCTION

A large number of transparent plastic films have been developed by industry in the last twenty-five years.[1] All of these films have useful properties in some form of packaging. They are designed, however, for industrial packaging where deteriorating conditions are specific and the expected storage life of the product rarely exceeds six months.[2] Military packaging materials, on the other hand, must provide protection for extended periods of time under all types of deteriorating conditions.[3]

Presently, no film is available which has all of the properties required for military packaging. By laminating two or more dissimilar films, the weaknesses inherent in the individual films can be reduced or eliminated.[4]

The vast number of possible composite films makes it necessary to predict the properties of composities prior to their fabrication. This can be accomplished if the properties of the individual films are known.[5] The presentation of properties (both specific and general) of such individual plastic films along with discussions concerning their usefulness in the preparation of needed transparent barrier materials for military applications[4] provides the scope of this report.

PROCEDURE

Material:

Noncomposite plastic films, as received from commercial suppliers.

Testing:

1. Tensile (Breaking) Strength - According to ASTM Tentative Method No. D 882-61T, Method A except that a rate of jaw separation of 12 inches per minute and a 2 inch gage length were used for all specimens. Specimen width was 1.0 inches.

2. Yield Strength - Same procedure as tensile strength.

3. Elongation - Same procedure as tensile strength.

4. Seam Strength - Same procedure as tensile strength except that a rate of jaw separation of 1.2 inches per minute was used for all materials whose elongation was less than 600% and the specimen width was 0.5 inches. The resistance of the seam to rupture was measured rather than the material.

5. Tearing Strength - According to Federal Test Method Standard No. 406, Method 1121.

6. Puncture Resistance - The resistance of material to rupture by a rounded, cylindrical penetrator, 0.19 inches in diameter, traveling at a constant rate of 12 inches per minute was determined. The Instron Testing Machine with the compression load cell attached and a suitable specimen holder were utilized.[4]

7. Blocking - According to Federal Test Method Standard No. 406, Method 1131 except that testing temperatures used were 150°F, 165°F, 180°F and 200°F. Rating of results was either blocking or no blocking at each temperature.

8. Grease Resistance - According to MIL-B-3959A, paragraph 4.5.4 except that the test was continued for five days.

9. Moisture Vapor Transmission Rate - According to MIL-B-3959A, paragraph 4.5.3 except that the specimens were not creased.

10. Acidity, pH - According to Federal Specification UU-P-31b, Method 200.

11. Fungus Resistance - According to Federal Specification CCC-T-191h, Method 5751.1 except that Aspirgillus niger, Aspirgillus terreus and Aspirgillus flavus were used in addition to Chaetomium globosum.

12. Corrosivity - 1/2 inch by 4 inch polished and solvent cleaned metal strips (copper and steel) were wrapped with plastic film, placed in a sealed test tube and subjected to elevated temperature for 60 days. Initial testing was conducted at 160°F. Those materials which caused corrosion were then tested at 130°F. After 60 days, the specimens were taken from the test tubes, the film was removed from the metal strips, and the metal finish

was inspected for corrosion. The rating of corrosiveness was accomplished using standard methods:

Copper - ASTM Copper Strip Corrosion Standards; Method D130.

Steel - ASTM Bulletin No. 154.[6]

13. Heat Storage Stability - Three adjacent samples of selected plastic films of sufficient size for testing were taken from the film rolls. One of these samples was tested for various properties to obtain control (original) values. The other two samples were placed in an oven maintained at 160 ± 2°F. These samples were removed after (1) 30 days and (2) 90 days, allowed to condition at 73 ± 2°F and 50% R.H. for 24 hours or more, and tested under the same conditions used for the controls. The properties determined were MVTR, seam strength, breaking strength, elongation, tearing strength, grease resistance and acidity. Methods used for these determinations are indicated above.

RESULTS

The data and results are shown in Tables I through VI.

DISCUSSION

A number of plastic films have been received from industry and evaluated for properties of interest to the military for packaging applications. Thirty-five of these were received and tested during FY 63. These were reported earlier[4] but have been included in this report (Table I) to provide continuity. Ten additional films were received during FY 64. They have been evaluated by the same methods as used for those received earlier (see Table II). Three of these films are noteworthy: (1) Fluorocarbon C has an extremely low MVTR and (2) Polyester D and biaxially oriented polypropylene have exceptionally good tensile strength and puncture resistance. Polyvinylidene fluoride and the polyimide also have good physical properties but their cost is excessive at present. The transparency of the polyimide is not acceptable for military packaging needs.

Fifteen plastic films were chosen from the list of available plastics as representative of plastic film types and were tested for fungus resistance, corrosivity to metals and storage stability at elevated temperatures (see Tables III, IV and V). It is realized that all films of a particular type do not have identical characteristics but, in respect to these three properties, they should be similar.

TABLE I

PROPERTIES OF NONCOMPOSITE FILMS DETERMINED IN FY 63

PLASTIC	DESCRIPTION	THICKNESS TESTED (Mil)	TENSILE STRENGTH (psi) MD	TENSILE STRENGTH (psi) CD	ELONGATION (%) MD	ELONGATION (%) CD	YIELD STRENGTH (psi) MD	YIELD STRENGTH (psi) CD	TEARING STRENGTH (#/in.) MD	TEARING STRENGTH (#/in.) CD	PUNCTURE RESISTANCE (#/in.)	WVTR (gms/100 in²/24 Hrs/Mil)	GREASE RESISTANCE	BLOCKING TEMP. (°F)	ESTIMATED COST ($/Lb.)
Fluorocarbon A[1]		2.0	11,180	4,610	140	350	4,340	3,600	600	540	4,290	0.08	Res.	>200	6.00
Fluorocarbon B[1]		2.0	7,100	5,660	40	30	7,100	5,660	280	210	2,970	0.12	Res.	>200	6.00
Trifluorochloro-ethylene		2.7	7,930	5,050	150	290	3,700	3,460	550	520	4,650	0.13	Res.	>200	6.00
Trifluorochloro-ethylene		5.0	7,430	5,860	250	300	4,550	4,100	500	460	4,150	0.16	Res.	>200	6.00
Polypropylene	Oriented	1.0	27,320	14,970	50	40	None	None	170	300	11,200	0.46	Not Res.	>200	1.40
Polyethylene	Med. Density	2.0	2,800	2,700	>600	>600	2,300	2,520	900	840	1,360	0.62	Not Res.	>200	0.42
Cellophane	Coated with Nitrocellulose	1.0	18,790	10,110	20	80	None	None	380	230	5,380	0.62	Res.	150	0.65
Polyester A[2]		2.1	8,830	6,680	80	90	None	None	360	330	3,800	0.66	Res.	>200	2.25
Polyethylene	Coated High Density	1.5	8,140	2,610	450	>600	2,760	2,610	1,120	900	2,170	0.68	Not Res.	150	1.00
Cellophane	Polymer Coated	1.4	17,490	7,810	20	50	None	6,450	50	40	3,450	0.72	Res.	>200	0.60
Cellophane	Polymer Coated	1.0	17,330	8,630	10	50	None	7,030	50	40	3,970	0.73	Res.	200	0.60
Rubber Hydro-chloride	Coated	1.3	4,860	4,810	100	50	4,860	4,810	1,900	1,300	2,770	0.77	Res.	>200	1.10
Polypropylene	Coated	2.0	6,360	5,220	>600	>600	3,380	3,250	1,260	1,270	1,530	0.80	Not Res	150	1.05
Polyprop. A[3]	Unoriented	2.0	4,660	4,820	>600	>600	3,170	3,010	1,010	980	1,720	0.82	Not Res.	200	0.65
Polyprop. B[3]	Unoriented	2.2	4,700	3,840	>600	>600	3,170	3,140	1,340	1,060	1,950	0.84	Not Res.	>200	0.65
Rubber Hydro-chloride	Coated	1.7	4,280	4,110	80	90	4,280	4,110	1,610	1,030	2,670	1.09	Res.	>200	1.10
Polyvinylidene Chloride A	High Permeability Rating	2.0	13,330	8,940	80	180	None	None	910	810	6,000	1.17	Res.	180	1.75
Polyethylene	Low Density	2.0	2,130	1,960	>600	>600	None	1,250	510	580	1,000	1.22	Not Res.	200	0.40
Polyethylene	Irradiated	2.0	12,910	10,460	80	120	None	None	580	590	7,720	1.37	Not Res.	200	1.05
Polyester B[2]		2.0	17,060	15,520	80	90	10,950	9,530	120	130	9,010	1.65	Res.	>200	2.25
Polyester C[2]		2.2	24,360	24,360	110	160	None	None	430	460	11,920	1.80	Res.	>200	2.25
Polyvinyl Fluoride		1.9	20,840	19,210	200	180	None	None	1,380	1,410	12,000	2.02	Res.	>200	5.00
Polyvinyl Chloride A[4]	Oriented	2.0	13,160	6,980	160	490	5,030	4,480	750	690	5,800	6.23	Res.	>200	0.60
Polyvinyl Chloride B[4]	Oriented	1.3	7,270	5,300	230	260	3,550	3,440	720	760	3,870	6.76	Res.	>200	0.80
Polystyrene	Oriented	1.0	10,560	10,240	410	20	None	10,240	40	70	2,890	8.29	Not Res.	200	0.60
Polycarbonate		2.0	12,370	12,390	180	180	9,060	8,320	350	370	7,180	8.89	Res.	>200	2.00
Polyvinyl Chloride-Acetate		3.5	4,180	3,720	390	470	None	None	730	690	2,630	9.66	Res.	180	0.65
Polyamide	Nylon - 6	1.5	13,110	6,900	450	450	6,430	5,680	1,640	1,680	3,890	13.53	Res.	>200	2.00
Polyurethane	Opaque	5.0	5,950	4,620	>600	310	None	None	840	560	2,700	>Test Limits	Res.	>200	2.00
Polyvinyl Acetate-Butyrate		5.0	7,790	5,970	100	140	6,040	5,470	90	80	4,010	>Test Limits	Res.	>200	1.00
Cellulose Acetate		3.5	8,340	7,610	40	70	7,900	7,150	60	50	3,830	>Test Limits	Res.	>200	0.90
Cellulose Tri-acetate		2.0	13,210	12,620	20	30	12,060	10,870	50	50	3,020	>Test Limits	Res.	>200	0.80
Ethyl Cellulose		2.1	10,640	11,840	30	50	9,410	8,900	70	70	6,040	>Test Limits	Not Res.	>200	1.20
Cellulose Propionate		5.0	6,070	5,440	80	90	6,070	5,440	220	260	3,540	>Test Limits	Res.	>200	1.00
Polyvinyl Alcohol		2.0	8,200	8,050	470	280	None	None	1,150	1,150	3,790	Water Soluble	Res.	>200	2.00

1 - Material differs in crystallinity level. 2, 3, 4 - Material obtained from different suppliers.

NOTE: The data contained in this table was presented earlier in RIA Technical Report No. 63-2482.

TABLE II

PROPERTIES OF NONCOMPOSITE FILMS DETERMINED IN FY 64

Plastic	Description	Thickness Tested (mil)	Tensile Strength (PSI) MD	Tensile Strength (PSI) CD	Elongation (%) MD	Elongation (%) CD	Yield Strength (PSI) MD	Yield Strength (PSI) CD	Tearing Strength (#/in.) MD	Tearing Strength (#/in.) CD	Puncture Resistance (#/in.)	WVTR (gms/100 in.², 24 hrs/mil)	Grease Resistance	Blocking Temp. (°F.)	Estimated Cost ($/lb.)
Polyallomer		2.0	5,540	4,620	>600	>600	2,400	2,420	1,060	940	1,600	1.22	Not Res.	200	1.00
Polyolefin A[3]	Oriented	0.7	35,540	8,060	40	410	None	5,060	770	2,940	6,290	0.48	Not Res.	>700	0.95
Fluorocarbon C[1]		0.5	13,200	7,280	30	100	None	7,260	520	1,480	6,000	0.02	Not Res.	>200	6.00
Polyester D[2]		1.0	43,900	11,780	40	140	None	13,020	370	1,700	12,500	1.41	Res.	>200	2.00
Polyvinylidene Chloride B	Low Permeability Rating	2.0	15,770	15,300	100	130	None	None	950	1,090	6,100	0.34	Res.	200	1.10
Polypropylene	Biax. Oriented	1.1	29,850	25,770	80	70	None	None	200	1,160	7,730	0.30	Not Res.	160	1.05
Polyvinylidene Fluoride		1.1	7,800	6,170	20	50	7,800	8,170	2,380	2,240	3,650	2.28	Res.	>200	12.00
Polyolefin B[3]		1.8	20,660	3,530	30	10	None	None	2,460	550	2,240	0.21	Res.	>200	0.96
Polyimide		2.0	26,920	21,600	60	60	None	None	670	760	11,090	5.42	Res.	>200	5.00
Polyolefin C[3]	Anti-Stick Treatment	2.0	4,240	3,160	310	340	None	None	550	530	1,910	>Test Limits	Not Res.	200	1.00

1 - Material differs from Fluorocarbons A and B in Crystallinity level.
2 - Material is from the same supplier as Polyester C but is of a different manufacturing process.
3 - Material obtained from different suppliers: all are experimental.

TABLE III

FUNGUS RESISTANCE OF PLASTICS

Plastic	Fungus Resis.	Plastic	Fungus Resis.
Fluorocarbon C	No growth	Polyvinyl fluoride	No growth
Polypropylene (Oriented)	" "	Polyvinyl Chloride A (Oriented)	Moderate growth
Polypropylene A (Unoriented)	" "	Polystyrene (Oriented)	No growth
Polyethylene (med. density)	" "	Polycarbonate	" "
Polyester D	" "	Polyamide (Nylon-6)	Sparse growth
Cellophane (nitro-cellulose coated)	Profuse growth	Cellulose Acetate	" "
Polyvinylidene Chloride B	Sparse growth	Polyallomer	No growth
Rubber Hydrochloride (1.7 mil)	" "		

TABLE IV

RESISTANCE OF PLASTIC FILMS TO STORAGE AT ELEVATED TEMPERATURES (160°F)

	Fluorocarbon C	Polypropylene (Oriented)	Polyprop A (Unoriented)	Polyethylene (Med. density)	Polyester D	Cellophane (Nitro-Cell. Coated)	Polyvinylidene Chloride B	Rubber Hydro-Chloride D	Polyvinyl Fluoride	Polyvinyl Chloride (Oriented)	Polystyrene (Oriented)	Polycarbonate	Polyamide (Nylon-6)	Cellulose Acetate
WVTR (gms/100 in²/24 hrs)														
Original	0.06	0.43	0.43	0.30	1.40	0.60	0.18	0.61	1.10	N.T.	N.T.	N.T.	N.T.	N.T.
30 days	0.06	0.42	0.35	0.31	1.36	*	0.18	0.72	1.05	-	-	-	-	-
90 days	0.06	0.38	0.32	0.31	1.30	*	0.13	0.96	1.01	-	-	-	-	-
Seam Strength Sealed & Aged (#/in)														
Original	1.6	7.2	7.6	4.4	6.8	0.5	7.4	6.0	7.6	7.4	0.7	4.9	6.0	3.6
30 days	1.3	8.6	8.6	5.0	3.6	*	4.6	5.2	7.6	8.2	0.7	7.3	6.6	2.4
90 days	3.3	8.0	8.8	2.8	6.0	*	5.0	4.2	7.8	10.0	0.7	4.8	4.8	3.6
Seam Strength Aged & Sealed (#/in)														
Original	1.8	7.2	7.8	4.4	6.8	0.8	7.4	6.0	7.6	7.4	0.7	6.6	4.0	3.6
30 days	2.4	5.2	8.4	5.0	6.6	*	3.2	3.4	6.2	8.4	0.7	8.2	7.4	3.0
90 days	3.3	5.6	9.2	4.0	8.2	*	0.2	4.2	6.8	10.8	0.4	4.8	7.2	3.3
Grease Resistance														
Original	Not Res.	Not Res.	Not Res.	Not Res.	Res.	Res.	Res.	Res.	Res.	Res.	Not Res.	Res.	Res.	Res.
30 days	-	-	-	-	-	*	-	-	-	-	-	-	-	-
90 days	-	-	-	-	-	*	Not Res.	-	-	-	-	-	-	-
Breaking St. (MD)(#/in)														
Original	6.6	30.8	9.9	6.8	46.8	18.3	21.3	[illegible]	28.2	13.8	11.2	34.8	17.3	30.8
30 days	5.7	29.8	18.3	6.2	44.8	*	20.6	5.2	34.9	19.5	10.5	28.5	18.0	31.8
90 days	7.8	21.6	19.8	5.4	44.1	*	27.6	5.0	27.4	17.8	10.8	21.8	14.2	31.4
Elongation (MD)(%)														
Original	30	40	>600	>600	30	30	90	110	190	260	4	180	280	80
30 days	30	30	>600	>600	30	*	120	76	170	310	4	190	300	50
90 days	40	30	>600	350	30	*	80	200	180	230	4	480	340	50
Tearing St. (MD)(#/in)														
Original	0.2	0.3	3.5	1.7	0.4	0.4	1.6	2.8	4.1	1.8	0.1	1.0	3.0	0.3
30 days	0.2	0.2	2.8	1.7	0.3	*	2.2	1.9	3.6	3.3	0.1	1.6	2.6	0.3
90 days	0.2	0.2	3.2	1.8	0.3	*	3.3	1.4	3.6	3.3	0.1	1.2	2.9	0.2
Acidity (pH Units)														
Original	6.6	6.7	6.7	6.9	6.7	4.5	6.4	4.6	6.8	6.4	6.7	6.6	5.9	5.4
30 days	6.6	6.6	6.6	6.8	6.9	*	5.9	4.1	6.5	5.5	6.6	6.2	5.2	5.6
90 days	6.6	6.5	7.0	6.4	6.8	*	4.6	4.0	6.5	5.5	7.2	6.7	5.1	5.5

* Blushing and Brittleness of this material was too severe for testing

TABLE V

CORROSIVENESS OF PLASTICS TO COPPER AND STEEL

Plastic	Copper 160° Rating*	Copper 160° Descrip.	Copper 130° Rating*	Copper 130° Descrip.	Steel 160° Rating**	Steel 160° Descrip.	Steel 130° Rating**	Steel 130° Descrip.
Fluorocarbon C	1B	No Cor.	Not Tested		9/s/9	Very Mild	Not Tested	
Polypropylene (Oriented)	1B	"	"	"	9/d/9	Very Mild	"	"
Polypropylene A (Unoriented)	2A	Very Mild	"	"	10/0/10	No Cor.	"	"
Polyethylene (med. density)	1A	No Cor.	"	"	10/0/10	" "	"	"
Polyester D	1B	No Cor.	"	"	10/0/10	" "	"	"
Cellophane (nitro-cellulose coated)	3A	Moderate	1B	No Cor.	10/0/10	" "	"	"
Polyvinylidene Chloride B	3B	Severe	Not Tested		0	Severe	5/a/7	Moderate
Rubber Hydrochloride (1.7 mil)	3B	Severe	3A	Moderate	0	"	0	Severe
Polyvinyl Fluoride	1B	No Cor.	Not Tested		10/0/10	No Cor.	Not Tested	
Polyvinyl Chloride A (Oriented)	3A	Moderate	1B	No Cor.	1/a/5	Severe	9/s/7	Mild
Polystyrene (Oriented)	3A	"	1A	No Cor.	10/0/10	No Cor.	Not Tested	
Polycarbonate	1B	No Cor.	Not Tested		10/0/10	" "	"	"
Polyamide (Nylon-6)	3A	Moderate	1A	No Cor.	10/0/10	" "	"	"
Cellulose Acetate	1B	No Cor.	Not Tested		10/0/10	" "	"	"
Polyallomer	1B	No Cor.	"	"	10/0/10	" "	"	"

* Rating of Copper is according to ASTM Method D130
** Rating of Steel is accoring to ASTM Bulletin No. 154

TABLE VI

SUMMARIZED COMPARISON OF PLASTIC FILM PROPERTIES

Type Plastic	MVTR	Tensile St.	Tearing St.	Puncture Res.	Grease Res.	Fungus Res.	Corrosiveness to Metals	Heat* Storage Stability	Heat** Sealability
Fluorocarbon	Very low	Moderate	Moderate	Moderate	Res.	Resistant	Not Corrosive	Good	Fair
Polypropylene (Oriented)	Low	Very high	Low	Very high	Not Res.	Resistant	Not Corrosive	Good	Excellent
Polypropylene (Unoriented)	Low	Very low	High	Very low	Not Res.	Resistant	Not Corrosive	Good	Excellent
Polyethylene	Low	Very low	High	Very low	Not Res.	Resistant	Not Corrosive	Fair	Good
Polyester (Uncoated)	High	Very high	Moderate	Very high	Res.	Resistant	Not Corrosive	Excellent	Erratic
Cellophane (Coated)	Moderate	Moderate	Low	Moderate	Res.	Severely Attacked	Corrosive to Copper	Very poor	Very poor
Polyvinylidene Chloride	Low	Moderate	High	High	Res.	Slightly Attacked	Corrosive to Copper and Steel	Very poor	Erratic
Rubber Hydrochloride	Moderate	Low	Very high	Low	Res.	Slightly Attacked	Corrosive to Copper and Steel	Poor	Good
Polyvinyl Fluoride	High	Very high	Very high	Very high	Res.	Resistant	Not Corrosive	Excellent	Good
Polyvinyl Chloride	Very high	Low	Moderate	Moderate	Res.	Moderately Attacked	Corrosive to Copper and Steel	Fair	Excellent
Polystyrene	Very high	Moderate	Very low	Low	Not Res.	Resistant	Corrosive to Copper	Good	Very poor
Polycarbonate	Very high	Moderate	Low	High	Res.	Resistant	Not Corrosive	Good	Fair
Polyamide	Very high	Moderate	Very high	Low	Res.	Slightly Attacked	Corrosive to Copper	Good	Fair
Cellulose Acetate	Very high	Low	Very low	Low	Res.	Slightly Attacked	Not Corrosive	Excellent	Poor
Polyallomer	Very high	Low	High	Very low	Not Res.	Resistant	Not Corrosive	N. T.	Poor

* Storage Stability is rated according to visual observations in addition to the data shown in Table IV
** Heat Sealability is rated according to relative difficulty encountered in sealing as well as strength of seals shown in Table IV. Impulse sealing, only, is considered.

Fungus resistance, an important feature for packaging materials used in tropical or subtropical climates, is generally characteristic of plastics. As can be seen from Table III, however, cellophane and the vinyls are susceptible to fungal attack and polyvinylidene chloride, rubber hydrochloride, polyamide and the cellulosics are not completely resistant. The medium conducive to growth of fungus in polyvinyl chloride is probably the plasticizer since it is reported[7] that PVC is resistant to attack by microorganisms. The cultures chosen for the test are among those commonly associated with package deterioration.

The temperatures used in the storage stability testing is higher than that anticipated for any normal storage conditions. The deterioration of properties, shown in Table IV, would be expected to develop over a longer period of time. These values should indicate, however, the relative resistance to heat storage of the various plastics. In other words, this is an accelerated aging test. Results of tests performed on plastic films are not highly reproducible and, therefore, minor discrepancies in the values have been disregarded. Variations in properties of sufficient magnitude to be considered as evidences of deterioration are:

(1) Rubber hydrochloride becomes less effective as a barrier against moisture vapor.

(2) The seam strength of polyethylene, polyvinylidene chloride and rubber hydrochloride (sealed and aged) is appreciably lowered.

(3) The sealing capabilities of rubber hydrochloride and polystyrene are reduced, those of polyamide and polycarbonate apparently increased, and that of polyvinylidene chloride is destroyed after 90 days of storage.

(4) The resistance of polyvinylidene chloride to grease is reduced.

(5) The breaking strength of rubber hydrochloride is reduced by more than 30% after the 90 day storage.

(6) The tearing strength of rubber hydrochloride is reduced by almost 30%. That of polyvinyl chloride is increased with exposure to heat but this is probably due to shrinkage of the film.

(7) The elongation of rubber hydrochloride is almost doubled and that of polyethylene is drastically reduced, both conditions being possible indications of deterioration.

(8) Polyvinylidene chloride, rubber hydrochloride, polyvinyl chloride, polyamide and polyethylene suffered moderate to high increases in acidity which is direct evidence of changes in chemical composition.

(9) The sample of cellophane became brittle and blocked so badly that testing could not be performed after 30 days exposure.

(10) The sample of polystyrene blocked slightly but test specimens showed little deterioration with the exception of heat sealability as noted above.

The corrosiveness of plastics to metals, a characteristic which would disqualify a material from any military application where there was contact with metals at temperatures above normal, is shown in Table V. Polyvinylidene chloride, rubber hydrochloride and PVC, to a lesser extent, are corrosive to both copper and steel. Cellophane, polystyrene and polyamide are moderately corrosive to copper at the high temperatures (160°F) only and do not affect steel at that temperature. Testing of this property at 130°F was not performed on material which caused no corrosion at 160°F.

Table VI summarizes the properties of the plastic film types and is the major reference for the following discussion concerning selection of components for transparent barrier materials.

A transparent barrier material at a reasonable cost which would afford protection equivalent to the currently used opaque packaging materials described by Military Specification MIL-B-131 is needed.[4] A few films, comparable in properties to the MIL-B-131 materials, have been marketed but their cost is excessive ($1.40 to $1.50 per square yard). The properties of the desired composite are: (1) transparency, (2) nominal thickness (5 mils or less), (3) extremely low MVTR, (4) non-corrosiveness to metals, (5) grease resistance, (6) fungus resistance, (7) excellent heat sealability (8) stability to storage at elevated temperatures, and (9) high physical strength characteristics.

Presently available composite plastic films conforming to these requirements utilize a three-component system. In order to reduce the cost of such fabrications, either (1) a two-component system must be used or (2) cheaper components must be selected. The former is preferred since the physical addition of a third component drastically increases the composite price.

The extremely low MVTR requirement makes it necessary that a fluorocarbon be used as one of the components. (No other material having this property at a reasonable thickness is available). Since this is a very expensive material, the lowest possible thickness must be utilized. It can also be established that this material must be the outer ply because (1) the wastage involved in the laminating process makes it imperative that this expensive item not be used as the middle ply where it would be laminated twice and (2) it does not have the heat sealability required for use as the inner ply. Fluorocarbon C, then, at approximately 1/2 mil must be used as the outer ply.

Since the fluorocarbon at this thickness offers very little in additional properties, the second component of a two-component system would be required to furnish the remaining characteristics. Some moisture vapor resistance would also be desired since the fluorocarbon at this thickness is borderline in meeting MIL-B-131. Only two films evaluated have promise toward meeting these requirements: (1) polyvinyl fluoride which is excessively expensive and (2) the polyesters whose heat-sealing characteristics are questionable.

Several reasonably priced films offer possibilities as the center ply of a three-component system. These include the polyesters, oriented polypropylene, irradiated polyethylene, polycarbonate and possibly polyamide if it can be established that it would not induce copper corrosion from this position.

The material selected for the inner ply must have excellent heat-sealability and be non-corrosive to metals in all cases. A high tearing strength and a low MVTR are necessary in certain fabrications. Two materials are available at low cost which meet these requirements: conventional medium density polyethylene and unoriented polypropylene. Polypropylene is superior to polyethylene in storage stability, particularly in regard to seam strength, and is considered more appropriate for this application.

In summation, a three-component system composed of (1) fluorocarbon C (1/2 mil), (2) a reasonably priced component featuring high strength characteristics and (3) unoriented polypropylene should provide the military with an improved transparent barrier material at a reduced cost. A two-component system composed of (1) fluorocarbon C (1/2 mil) and (2) a polyester with excellent heat sealing characteristics (if such is available) should result in an acceptable material at an even greater reduction in cost.

Six composite films (two -2 component systems and four -3 component systems as discussed above) are presently being prepared by industry at RIA request for evaluation at Rock Island Arsenal Laboratory.

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Data is presented on the properties of ten recently received plastic films along with data on thirty-five films reported earlier. Fifteen films, selected from this group as representative of plastic film types, were tested for fungus resistance, corrosiveness to metals, and stability to storage at elevated temperatures. Polyvinylidene chloride, rubber hydrochloride and polyvinyl chloride were found to be corrosive; cellophane and polyvinyl chloride are not fungus resistant;
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